Fish Habitat Utilization in a Puerto Rico Coral Reef Ecosystem

RANDY CLARK[1], MARK E. MONACO[1], RICHARD S. APPELDOORN[2], and BRYANT ROQUE[2]
[1]NOAA/NOS/NCCOS/CCMA Biogeography Team
1305 East-West Highway, N/SCI 1
Silver Spring, Maryland 20910 USA
[2]University of Puerto Rico
Department of Marine Sciences, Isla Magueyes
B.O. La Parguera
Lajas, Puerto Rico 00667

ABSTRACT

Over the past three years, the National Center for Coastal Ocean Science's (NCCOS) Center for Coastal Monitoring and Assessment (CCMA), in cooperation with the University of Puerto Rico's Marine Science Department, has conducted biological monitoring activities in La Parguera, Puerto Rico. Since many tropical fishes exhibit small or large scale migrations associated with foraging, passive fishing gears were deployed to capture adult and sub-adult fishes among several habitat types within the coral reef ecosystem to examine the relationship between fish habitat utilization patterns and habitat function. Three replicates of 100 meter gill nets were deployed to determine fish movements across four habitat types, seagrass/reef, seagrass/mangrove, seagrass/ unconsolidated bottom and, mangrove/unconsolidated sediments, located within three zones; lagoon, outer lagoon, and bank shelf. Nets were set proximal and parallel to habitat edges such that fishes moving across these boundaries were captured. This, coupled with gut content analyses will provide information necessary to describe feeding related migrations and to assess habitat function.

From June 2000 through December 2002, 184 gill nets were deployed which captured 690 fishes comprising 72 species. Fish movement was inferred by noting fish orientation in the net and gut contents were removed in the laboratory and preserved for identification. Gut contents were identified to the lowest possible taxon and weighed (g).

Herein, we provide preliminary results that describe fish movements and dietary components which will be used to determine the functional role of habitats for specific species and/or trophic guilds. These results support efforts to define Essential Fish Habitat (EFH) for federally managed species and can also be used in conjunction with other monitoring data to define ecologically-relevant boundaries for Marine Protected Areas (MPA's).

KEY WORDS: coral reef ecosystem, fish, habitat function

Pesque la Utilización del Habitat en un Ecosistema de la Barrera Coralina de Puerto Rico

Sobre los pasados tres años, el Centro Nacional para la Ciencia (NCCOS) Costera de Océano Central para Controlar y Evaluación (CCMA) Costero, en la cooperación con el Univeristy de Puerto Rico el Departamento Marino de la Ciencia, ha conducido biológico controlando las actividades en La Parguera, Puerto Rico. Desde que muchos peces tropicales exhiben las migraciones pequeñas o en gran escala asociadas con adentrándose, engranajes pesqueros pasivos se desplegaron para capturar el adulto y peces sub adultos entre varios de tipo habitat dentro del ecosistema de la barrera coralina examinar la relación entre pautas de utilización de habitat de pez y función de habitat. Tres replican de 100 redes de la agalla de contador fueron desplegados para determinar los movimientos de pez a través de cuatro de tipo habitat, seagrass/escollo, seagrass/el mangle, seagrass/el fondo no consolidado y, el mangle/sedimentos no consolidados, localizado dentro de tres zonas; la laguna, la laguna exterior, y estante bancario. Las redes se pusieron próximo y la paralela a orillas de habitat tanto que peces moviera a través de estas fronteras fueron capturados. Esto, emparejado con el contenido de intestino analiza proporcionará información necesaria para describir alimentando las migraciones relacionadas y para valorar la función del habitat.

De junio 2000 por el 2002 de diciembre de 184 redes de agalla se desplegaron que capturó 690 peces que comprenden 72 especie. El movimiento del pez fue inferido notando la orientación de pez en el contenido de red e intestino se quitó en el laboratorio y preservó para la identificación. El contenido del intestino fue identificado al taxon posible más bajo y pesado (g).

En esto, nosotros proporcionamos los resultados preliminares que describen pez los movimientos y los componentes dietéticos que se utilizarán para determinar el papel funcional de habitates para gremios específicos de especie y/o trophic así como investiga la importancia del transporte del habitat de la cruz de la materia orgánica. Estos resultados sostienen los esfuerzos de definir el Habitat (EFH) Esencial de Pez para la especie federalmente manejada y se puede utilizar también en conjunción con otro controlando los datos para definir las fronteras ecológicamente pertinentes para el Marina Areas (MPA) Protegidas.

PALABRAS CLAVES: ecosistema de barrera coralina, el pez, la función del habitat

INTRODUCTION

Marine reserves are supported as a management option because they focus on protecting vulnerable fish spawning stock aggregations and preserving essential ecosystem components critical to growth and survival (Sluka et al. 1997, Appeldoorn 2001). Successful implementation of marine reserves requires a strong understanding of the linkages between fishes and the habitats that promote their recruitment, growth, feeding, and reproduction (Parrish

1989, Friedlander and Parrish 1998).

Many tropical fishes in coral reef ecosystems utilize a variety of habitats during their life histories, often exhibiting discriminate utilization of settlement, nursery, and spawning areas (Eggleston 1995, Appeldoorn et al. 1997, Eggleston et al. 1998), and typically these fishes migrate from one habitat to another for feeding (Ogden and Ehrlich 1977, McFarland et al. 1979, Burke 1995, Kendall 2002). Among these, knowledge of dietary components and sources are essential for understanding and evaluating habitat function, which can have long-term implications for fisheries resource management.

The National Oceanic and Atmospheric Administration's (NOAA) Center for Coastal Monitoring and Assessment (CCMA) and the University of Puerto Rico have been collaborating to monitor long-term patterns of fish distribution among benthic habitats off La Parguera, Puerto Rico. Objectives of this research include a digital geo-referenced benthic habitat map of the La Parguera coral reef ecosystem (Kendall et al. 2001), monitoring the abundance and distribution of fishes among the various habitats (Christensen et al. 2003), and assessing habitat function as it relates to fish foraging movements among habitats. The latter research objective is described herein, providing preliminary results that explore the possible linkages between fish and their habitats.

MATERIALS AND METHODS

Study Area

Gill net sampling was conducted quarterly, beginning in June 2000, between a variety of habitats across the insular shelf off La Parguera, Puerto Rico (Figure 1). A digital map of benthic habitats for this region (Figures 1 and 2) was used to randomly select habitat boundaries for sampling within the La Parguera reef ecosystem (Kendall et al. 2001). The habitat map was used to stratify the study area into eight zone/habitat boundary combinations or strata based on three zones and four habitat boundaries. The study area is comprised of three zones divided by emergent reefs: lagoon, outer lagoon, and bank shelf (Figure 1). Within these, four habitat boundaries were sampled, where present:

i) **lagoon** – seagrass/mangrove (LSM), seagrass/reef (LSR), seagrass/unconsolidated sediments (LSU), mangrove/unconsolidated sediments (LMU);

ii) **outer lagoon** – seagrass/mangrove (OLSM), seagrass/reef (OLSR), seagrass/unconsolidated sediments (OLSU); and,

iii) **bank shelf** – seagrass/reef (BSR). Only eight strata were possible due to the lack of mangroves on the bank shelf, insufficient areas of both seagrass/unconsolidated sediment boundaries on the bank shelf and mangrove/unconsolidated sediment boundaries in the outer lagoon.

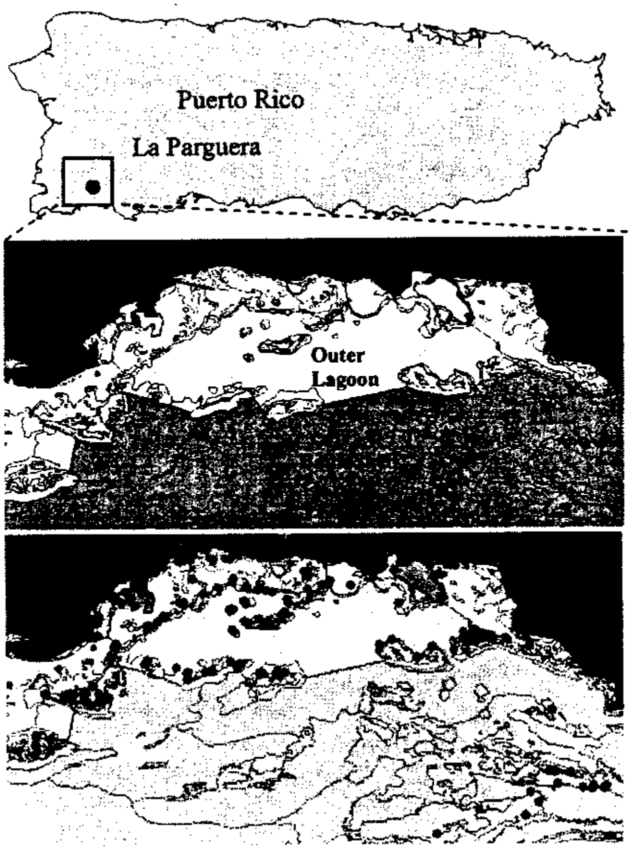

Figure 1. Map of La Parguera, Puerto Rico study area. Middle inset displays three zones (lagoon, outer lagoon, and bank shelf), while the lower inset exhibits the distribution of gill net sample locations.

EXPERIMENTAL DESIGN

During each trip, three replicates of 100 m gill net were deployed at each of the 8 possible habitat strata totaling 24 gill net deployments per sampling trip. Inclement weather prohibited the deployment of nets at one or all bank shelf seagrass/reef sites during October 2001, February and June 2002. Additionally, seagrass/unconsolidated sediment habitats within the lagoon were added after the initial June 2000 trip. As a result, 184 nets were deployed during the study period.

Gill nets were constructed of 100 m nylon mesh (5 x 5 cm, 10 cm stretched) with standard float and lead lines. Nets were deployed as close to habitat boundaries as possible with caution taken to not set on reef structures or other habitat features. Nets were set near dusk and picked up at dawn; soak times ranged from 12-14 hours.

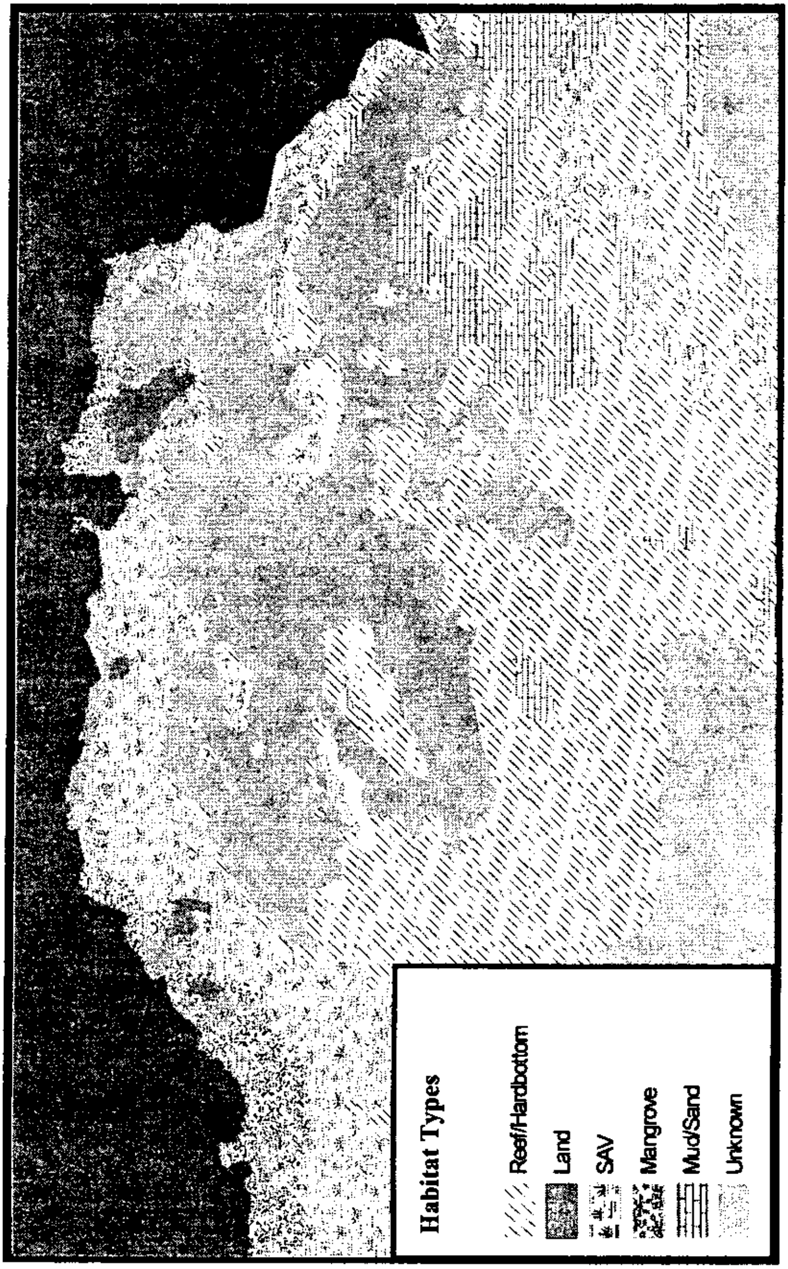

Figure 2. Classified benthic habitat map for the study area (Kendall et al. 2001).

During collection, fish movement was recorded by its orientation in the net, and all fishes sampled were stored on ice. In the laboratory, all captured fish were measured for fork, standard, and total length to the nearest 1 mm, and weighed to the nearest 1 g. Entire gastro-intestinal organs were excised and stored in 10 % formalin for 24 hours, then transferred to a 30 % ethanol solution. Stomach contents were removed, weighed to the nearest .01 g, and identified to the lowest possible taxon. Otoliths were also extracted from bony fishes and stored for future aging analyses.

STATISTICAL ANALYSES

Data were entered into a database and analyzed with JMP statistical software (Version 4.0, SAS Institute 2000). Total abundance and sighting frequency were calculated for each zone, habitat boundary, and stratum. Sighting frequency is the percentage of all gill net samples in which a particular species was captured (Table 1).

Table 1. Summary gill net catch data among habitat strata within the La Parguera coral reef ecosystem, June 2000 – December 2002. Habitat strata include lagoon mangrove unconsolidated sediment (LMU), lagoon seagrass mangrove (LSM), lagoon seagrass reef (LSR), lagoon seagrass unconsolidated sediment (LSU), outer lagoon seagrass mangrove (OLSM), outer lagoon seagrass reef (OLSR), outer lagoon seagrass unconsolidated sediment (OLSU), and bank shelf seagrass reef (BSR).

Habitat Strata	# of Sets	Fish Captured	Weight (kg)	Fish/Set	Weight (kg)/Set
LMU	24	81	65.3	3.4	2.7
LSM	24	52	75.2	2.2	3.1
LSR	24	101	86.7	4.2	3.6
LSU	21	151	94.4	7.2	4.5
OLSM	24	62	63.2	2.6	2.6
OLSR	24	112	83.2	4.7	3.5
OLSU	24	62	89.3	2.6	3.7
BSR	19	69	47.6	3.6	2.5
Total	184	690	604.9	3.7	3.3

Correspondence analysis was used to examine patterns of fish distribution among strata and/or habitat boundaries and prey items. Species that were infrequently captured, i.e. the lower 5th percentile of frequency of occurrence, were omitted from the analyses. Correspondence analysis is a graphical ordination that shows similarity between two variables, in this case fish or food item and strata, within a frequency table (SAS Institute 2000).

Identification of gut contents was variable. For crabs and fishes, identification to the family level was common; however, other taxa were only identified to the order level. As such, gut contents were grouped into broader categories to facilitate statistical analyses. These categories consisted of: crabs (primarily from the families Calappidae, Majidae, Portunidae, and Xanthidae); shrimps (primarily from the families Alpheidae and Penaeidae); other crustacea (predominantly from the orders Amphipoda, Isopoda, and Stomatopoda); molluscs (mostly gastropods and bivalves); fish; polychaetes; echinoderms (primarily urchins and starfish); and, algae/seagrass.

Bluestripe grunt, *Haemulon sciurus*, catch and gut content data were examined to explore ontogenetic linkages between habitat and prey items. ANOVA and correspondence analysis was used to observe possible shifts in habitat distribution and prey items.

RESULTS

Table 1 shows summary catch data for all gill net sets from June 2000-December 2002. A total of 184 gill nets were deployed among eight strata (see bottom inset of Figure 1 for sample locations). Approximately 10% of all deployments were unsuccessful at capturing fishes. Table 2 displays taxa captured by zone, habitat boundary, and habitat strata. A total of 690 fishes from 72 species were captured in good condition for gut content analyses. Sea bream, *Archosargus rhomboidalis*, accounted for approximately 20 % of the total abundance and was one of the dominant species among the soft bottom habitat boundaries. Gray snapper, *Lutjanus griseus*, and the bluestriped grunt, *Haemulon sciurus*, comprised 8 % of the total catch, respectively, while yellowfin mojarra, *Gerres cinereus*, accounted for 7 %. For the remainder of individual species abundance comprised 5 % or less of the overall total abundance.

Most species were present within one or two zones, while 11 were present within all three. Similarly, only seven species were taken at all habitat boundaries, and only two, *L. griseus* and *H. sciurus*, were captured within all strata (Table 2).

Approximately 17 % of stomachs extracted were empty. Of the identifiable gut contents, crabs were the most abundant prey item in terms of percent occurrence (Figure 3), while mollusca, algae/seagrass, fish, and other crustacea yielded greater than 10 % frequency of occurrence. Shrimp, polychaetes, and echinoderms were less common, with each having frequencies less than 6 %.

Table 2. Frequency of occurrence for all taxa captured in gill nets. Values are reported for overall frequency and frequency by zone, habitat boundary, and strata.

Family	Taxon	Total	Zone			Habitat Boundary				Habitat Strata							
		Cumulative Frequency (N=184)	Lagoon (N=93)	Outer Lagoon (N=72)	Bank Shelf (N=19)	Seagrass/Reef (N=67)	Seagrass/Mangrove (N=48)	Seagrass/Unconsolidated Sediment (N=45)	Mangrove/Unconsolidated Sediment (N=24)	Lagoon Mangrove/Unconsolidated Sediment (N=24)	Lagoon Seagrass/Mangrove (N=24)	Lagoon Seagrass/Reef (N=24)	Lagoon Seagrass/Unconsolidated Sediment (N=21)	Outer Lagoon Seagrass/Mangrove (N=24)	Outer Lagoon Seagrass/Reef (N=24)	Outer Lagoon Seagrass/Unconsolidated Sediment (N=24)	Bank Shelf Seagrass/Reef (N=19)
Acanthuridae	*Acanthurus bahianus*	0.01	.	0.33	.	0.03	.	.	.	.	.	.	.	.	0.08	.	.
	Acanthurus chirurgus	0.02	0.01	0.11	0.05	0.04	.	.	.	.	.	0.04	.	.	0.04	.	0.05
	Acanthurus coeruleus	0.03	.	0.31	0.21	0.07	.	.	.	.	.	.	.	.	0.04	.	0.21
Albulidae	*Albula vulpes*	0.06	0.03	0.36	.	0.01	.	0.22	.	.	.	.	0.33	.	0.04	0.13	.
Bothidae	*Bothus lunatus*	0.01	.	0.33	.	.	0.04	.	.	.	.	.	.	0.08	.	.	.
Carangidae	*Caranx bartholomaei*	0.01	.	.	0.05	0.01	.	.	.	.	.	.	.	.	.	.	0.05
	Caranx hippos	0.02	0.02	0.31	.	0.03	0.02	.	.	.	0.04	0.04	.	.	0.04	.	.
	Caranx latus	0.11	0.07	0.10	.	0.12	.	0.16	.	.	.	0.13	0.24	.	0.21	0.08	.
	Caranx ruber	0.08	0.01	0.38	0.16	0.12	0.02	0.02	.	.	.	0.04	.	0.04	0.17	0.04	0.16
	Chloroscombrus chrysurus	0.02	0.01	0.33	.	0.04	.	.	.	.	.	0.04	.	.	0.08	.	.
	Selar crumenophthalmus	0.01	.	.	0.05	0.01	.	.	.	.	.	.	.	.	.	.	0.05
	Selene vomer	0.02	0.02	0.31	.	.	.	0.02	0.08	0.08	.	.	.	.	.	0.04	.
	Trachinotus falcatus	0.03	0.03	0.33	.	0.03	0.04	0.02	.	.	0.04	0.08	.	0.04	.	0.04	.
Carcharhinidae	*Carcharhinus perezi*	0.01		0.11		0.01									0.04		
	Negaprion brevirostris	0.01	.	0.31	.	.	.	0.02	.	.	.	.	.	.	.	0.04	.
Centropomidae	*Centropomus undecimalis*	0.02	0.04		.	.	.	.	0.17	0.17	.	.	.	.	.	.	.
Clupeidae	*Opisthonema oglinum*	0.01	0.01		.	.	.	0.02	.	.	.	.	0.05	.	.	.	.
Dactylopteridae	*Dactylopterus volitans*	0.01	.	0.31	.	0.01	.	.	.	.	.	.	.	.	0.04	.	.
Dasyatidae	*Dasyatis americana*	0.09	0.05	0.10	0.16	0.07	0.13	0.04	0.13	0.13	0.08	.	0.05	0.17	0.08	0.04	0.16
Echeneidae	*Echeneis naucrates*	0.05	0.04	0.34	0.11	0.09	.	0.17	.	.	.	0.13	0.05	.	0.04	0.08	0.11
Elopidae	*Megalops atlanticus*	0.03	0.05		.	.	0.02	.	0.17	0.17	0.04	.	.	.	.	.	.
Ephippidae	*Chaetodipterus faber*	0.05	0.05	0.34	.	0.04	0.02	0.02	0.17	0.17	.	0.04	0.05	0.04	0.08	.	.
Gerreidae	*Eucinostomus lefroyi*	0.01	.	0.31	.	.	.	0.02	.	.	.	.	.	.	.	0.04	.
	Gerres cinereus	0.17	0.13	0.18	.	0.1	0.1	0.33	0.17	0.17	0.08	0.13	0.43	0.13	0.17	0.25	.

Table 2 continued. Frequency of occurrence for all taxa captured in gill nets. Values are reported for overall frequency and frequency by zone, habitat boundary, and strata.

		Total	Zone			Habitat Boundary				Habitat Strata							
Family	**Taxon**	Cumulative Frequency (N=184)	Lagoon (N=92)	Outer Lagoon (N=72)	Bank Shelf (N=19)	Seagrass/Reef (N=67)	Seagrass/Mangrove (N=48)	Seagrass/Unconsolidated Sediment (N=45)	Mangrove/Unconsolidated Sediment (N=24)	Lagoon Mangrove/Unconsolidated Sediment (N=24)	Lagoon Seagrass/Mangrove (N=24)	Lagoon Seagrass/Reef (N=24)	Lagoon Seagrass/Unconsolidated Sediment (N=21)	Outer Lagoon Seagrass/Mangrove (N=24)	Outer Lagoon Seagrass/Reef (N=24)	Outer Lagoon Seagrass/Unconsolidated Sediment (N=24)	Bank Shelf Seagrass/Reef (N=19)
Haemulidae	*Anisotremus virginicus*	0.31	.	0.01	.	0.01	.	.	.	.	.	.	.	.	0.04	.	.
	Haemulon aurolineatum	0.31	.	.	0.11	0.03	.	.	.	.	.	.	.	.	.	.	0.11
	Haemulon chrysargyreum	0.31	0.01	.	.	0.01	.	.	.	.	.	0.04	.	.	.	.	.
	Haemulon flavolineatum	0.32	0.02	0.03	.	0.04	.	0.02	.	.	.	0.04	0.05	.	0.08	.	.
	Haemulon parra	0.31	0.01	0.01		0.03						0.04			0.04		
	Haemulon plumieri	0.36	0.01	0.07	0.26	0.13	.	0.04	.	.	.	.	0.05	.	0.17	0.04	0.26
	Haemulon sciurus	0.21	0.24	0.19	0.16	0.19	0.27	0.18	0.21	0.21	0.33	0.21	0.19	0.21	0.21	0.17	0.16
	Haemulon striatum	0.31	0.01	0.01	.	0.03	.	.	.	.	.	0.04	.	.	0.04	.	.
Holocentridae	*Holocentrus adscensionis*	0.32	0.02	0.01	.	0.04	.	.	.	.	.	0.08	.	.	0.04	.	.
	Holocentrus marianus	0.31	0.01	0.01	.	0.03	.	.	.	.	.	0.04	.	.	0.04	.	.
	Holocentrus rufus	0.31	0.02	.	.	0.01	.	.	.	.	.	0.04	.	.	.	.	.
	Myripristis jacobus	0.33	0.04	0.03	.	0.07	.	0.02	.	.	.	0.13	0.05	.	0.08	.	.
Kyphosidae	*Kyphosus sectatrix*	0.34	0.03	0.07	.	0.12	.	.	.	.	.	0.13	.	.	0.21	.	.
Labridae	*Lachnolaimus maximus*	0.31	.	.	0.11	0.03	.	.	.	.	.	.	.	.	.	.	0.11
Lutjanidae	*Lutjanus analis*	0.10	0.11	0.11	.	0.04	0.02	0.27	0.08	0.03	0.04	0.04	0.29	.	0.08	0.25	.
	Lutjanus apodus	0.32	0.02	0.01	.	0.03	0.02	.	.	.	.	0.08	.	0.04	.	.	.
	Lutjanus cyanopterus	0.32	0.02	.	0.05	0.01	.	.	0.08	0.03	.	.	.	.	.	.	0.05
	Lutjanus griseus	0.21	0.31	0.11	0.05	0.09	0.27	0.22	0.38	0.33	0.33	0.13	0.43	0.21	0.08	0.04	0.05
	Lutjanus jocu	0.39	0.17	0.01	.	0.07	0.08	.	0.33	0.33	0.17	0.17	.	.	0.04	.	.
	Lutjanus synagris	0.32	.	0.03	0.05	0.01	.	0.04	.	.	.	.	.	.	.	0.08	0.05
	Ocyurus chrysurus	0.31	.	0.03	.	0.03	.	.	.	.	.	.	.	.	0.08	.	.
Mugilidae	*Mugil curema*	0.31	0.02	.	.	.	.	0.02	0.04	0.04	.	.	0.05	.	.	.	.
Mullidae	*Mulloidichthys martinicus*	0.32	0.01	0.03	0.05	0.03	.	0.04	.	.	.	.	0.05	.	0.04	0.04	0.05
Muraenidae	*Gymnothorax funebris*	0.31	0.01						0.04	0.04							

Table 2 continued. Frequency of occurrence for all taxa captured in gill nets. Values are reported for overall frequency and frequency by zone, habitat boundary, and strata.

		Total	Strata			Habitat Boundary				Habitat Strata							
Family	Taxa	Cumulative Frequency (N=184)	Lagoon (N=93)	Outer Lagoon (N=72)	Bank Shelf (N=19)	Seagrass/Reef (N=67)	Seagrass/Mangrove (N=48)	Seagrass/Unconsolidated Sediment (N=45)	Mangrove/Unconsolidated Sediment (N=24)	Lagoon Mangrove/Unconsolidated Sediment (N=24)	Lagoon Seagrass/Mangrove (N=24)	Lagoon Seagrass/Reef (N=24)	Lagoon Seagrass/Unconsolidated Sediment (N=21)	Outer Lagoon Seagrass/Mangrove (N=24)	Outer Lagoon Seagrass/Reef (N=24)	Outer Lagoon Seagrass/Unconsolidated Sediment (N=24)	Bank Shelf Seagrass/Reef (N=19)
Myliobatidae	*Aetobatus narinari*	0.04	0.06	0.03	.					0.04	0.04	0.04	0.14	.	.	0.08	.
Ostraciidae	*Lactophrys trigonus*	0.02	0.02	.	0.05	0.01	0.02	.	.	.	0.03	.	.	.	.	.	0.05
Pomacanthidae	*Pomacanthus arcuatus*	0.02	0.01	0.03	.	0.04		.	.	.	.	0.04	.	.	0.08	.	.
Rhincodontidae	*Ginglymostoma cirratum*	0.01	0.01	.	.	.	0.02	.	.	.	0.04	.	.	.	.	.	.
Scaridae	*Scarus guacamaia*	0.01	0.01	.	.	0.01		.	.	.	.	0.04	.	.	.	.	.
	Scarus vetula	0.01	0.01	0.01	.	0.03		.	.	.	.	0.04	.	.	0.04	.	.
	Sparisoma aurofrenatum	0.02	0.01	0.03	0.05	0.06		.	.	.	.	0.04	.	.	0.08	.	0.05
	Sparisoma chrysopterum	0.01	.	0.01	.	0.01		.	.	.	.	.	.	.	0.04	.	.
	Sparisoma viride	0.01	0.01	.	0.05	0.03		.	.	.	.	0.04	.	.	.	.	0.05
Sciaenidae	*Odontoscion dentex*	0.01	0.01	.	.	.	0.02	.	.	.	0.04	.	.	.	.	.	.
Scombridae	*Scomberomorus cavalla*	0.01	.	0.01	.	.		0.02	.	.	.	.	.	.	.	0.04	.
	Scomberomorus regalis	0.02	0.02	0.01	.	0.01		0.04	.	.	.	0.04	0.05	.	.	0.04	.
Scorpaenidae	*Scorpaena plumieri*	0.05	0.04	0.07	0.05	0.07	0.08	.	.	.	.	0.13	.	0.17	0.04	.	0.05
Soleidae	*Trinectes maculatus*	0.01	0.01	.	.	.		.	0.04	0.04	.	.	.	.	.	.	.
Sparidae	*Archosargus rhomboidalis*	0.16	0.23	0.13	.	.	0.31	0.18	0.29	0.29	0.25	.	0.38	0.38	.	.	.
	Calamus bajonado	0.02	.	0.04	.	0.03		0.02	.	.	.	.	.	.	0.08	0.04	.
	Calamus calamus	0.08	0.06	0.10	0.05	0.15		0.09	.	.	.	0.17	0.1	.	0.21	0.08	0.05
	Calamus penna	0.02	.	0.01	0.11	0.03		0.02	.	.	.	.	.	.	.	0.04	0.11
	Calamus pennatula	0.02	0.03	.	0.05	0.06		.	.	.	.	0.13	.	.	.	.	0.05
Sphyraenidae	*Sphyraena barracuda*	0.03	0.04	0.01	.	.	0.04	0.07	.	.	0.04	.	0.14	0.04	.	.	.
Stromateidae	*Peprilus alepidotus*	0.01	0.01	.	.	.		.	0.04	0.04	.	.	.	.	.	.	.
Synodontidae	*Synodus intermedius*	0.03	.	0.07	.	0.06	0.02	.	.	.	.	.	.	0.04	0.17	.	.
Tetraodontidae	*Diodon holocanthus*	0.03	0.01	0.06	.	0.01	0.06	0.02	.	.	.	0.04	.	0.13	.	0.04	.
	Diodon hystrix	0.13	0.12	0.17	.	0.12	0.19	0.09	0.08	0.08	0.13	0.25	.	0.25	0.08	0.17	.

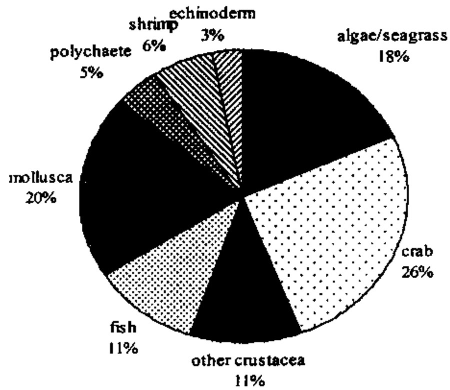

Figure 3. Percent occurrence of prey items from fishes captured in gill nets.

Species abundance among the eight strata were not significant, however, habitat-species correspondence analysis (Figure 4a) yielded statistically significant groupings for the four habitat boundaries investigated. The habitats displayed distinctive ordination between seagrass/reef, seagrass unconsolidated sediments and the combination of seagrass/mangrove and mangrove unconsolidated sediments. Most of the species captured shared ordination space with at least two habitat types. Seventeen species associated closely with the seagrass/reef habitats; these species were common reef species predominantly from the haemulid, acanthurid, sparid, holocentrid, and scarid families. Only two fishes (yellowfin mojarra, *Gerres cinereus*, and bonefish, *Albula vulpes*) associated exclusively with the seagrass/unconsolidated sediment habitats, while several species were shared among the seagrass/reef and seagrass mangrove habitats. Four species associated closely with mangrove/unconsolidated sediment habitats (peacock flounder, *Bothus lunatus*, common snook, *Centropomus undecimalis*, hogchoker, *Trinectes maculatus*, and tarpon, *Megalops atlanticus*). The seagrass/mangrove habitat was the only habitat type that was not exclusively used by any of the species captured in gill nets.

Correspondence analysis results for fish species and prey (Figure 4b) indicated a strong dependence on multiple prey types for most of the species captured. The correspondence plot displays three different feeding guilds for the species captured; piscivores, grazers (consumers of algae/seagrass), and omnivores (all other prey categories). The piscivorous fishes included snappers, barracuda, mackerels, jacks, and lizardfishes, while grazers consisted of angelfish, chubs, blue tang (*Acanthurus coeruleus*), and several species of parrotfish.

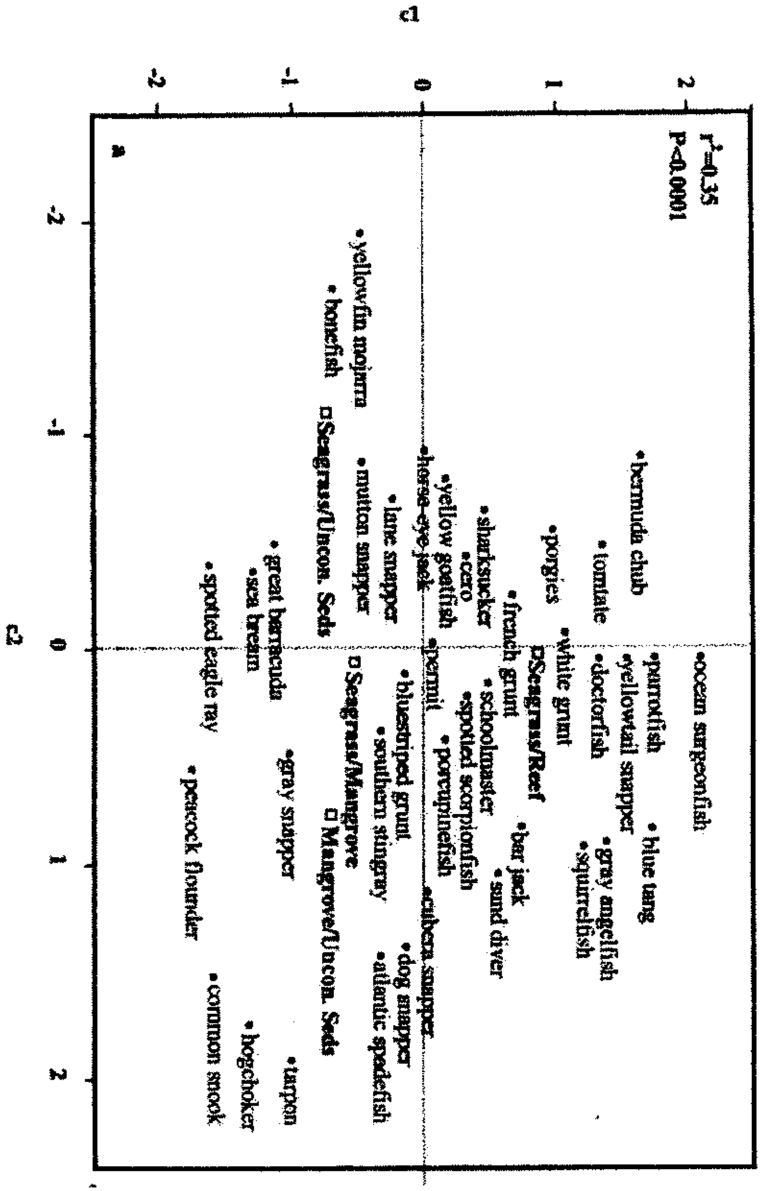

Figure 4a. Correspondence analysis results displaying the relationship between fish species captured in gill nets and habitat. Open squares represent habitat ordinations, while closed circles represent fish species ordinations.

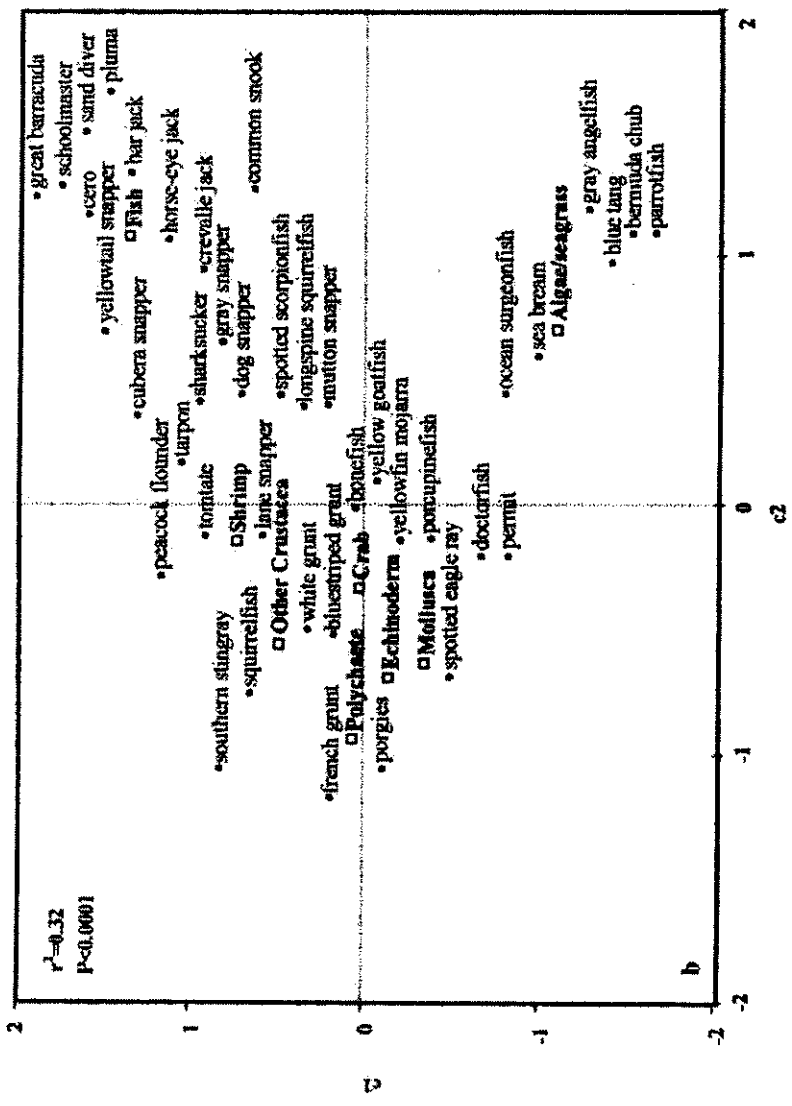

Figure 4b. Correspondence analysis results displaying the relationship between fish species captured in gill nets and prey item groupings. Open squares represent prey item ordinations, while closed circles represent fish species ordinations.

During the study, 52 bluestriped grunts (*H. sciurus*) were captured ranging in size from 86-265 mm standard length (Figure 5a). ANOVA was used to compare mean lengths among the eight strata sampled (Figure 5b). Results indicated that reef/seagrass habitats in all zones (lagoon, outer lagoon, and bank shelf) had significantly larger blue striped grunts than the vegetated and non-vegetated habitats. Correspondence analysis revealed significant differences in prey selection among habitats (Figure 6). Echinoderms were found in grunt gut contents from reef/seagrass habitats. Fish and crabs were found in both reef/seagrass and lagoon seagrass/mangrove and unconsolidated sediment habitats. Shrimp and other small crustaceans were consumed only in vegetated and nonvegetated habitats in the lagoon. Small molluscs and algae were consumed by grunts in the outer lagoon seagrass/mangrove habitats exclusively.

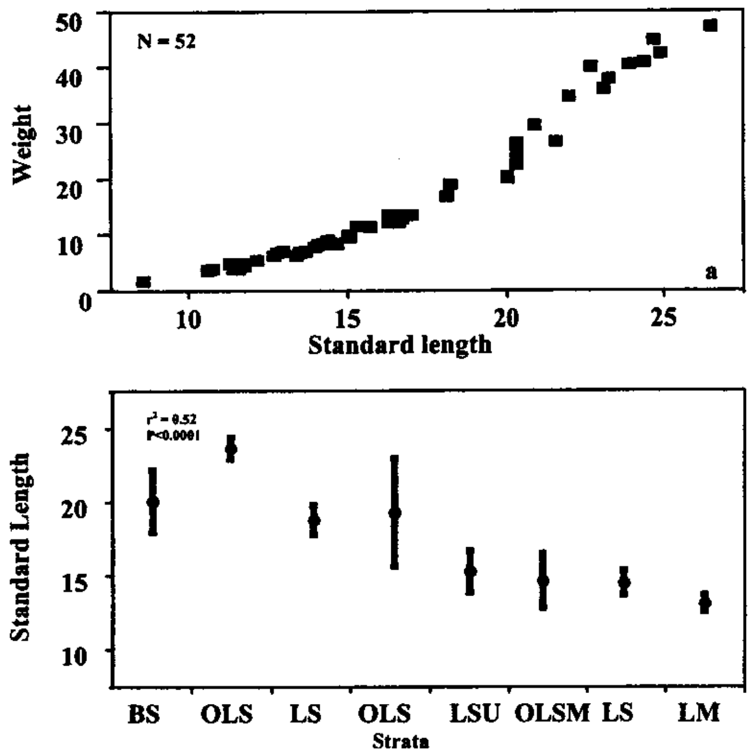

Figure 5. a) Bluestriped grunt, *Haemulon sciurus*, length-weight relationship. b) ANOVA results comparing bluestriped grunt standard length among sampled strata. BSR=bankshelf seagrass/reef; OLSR=outer lagoon seagrass/reef; LSR=lagoon seagrass/reef; OLSU=outer lagoon seagrass/unconsolidated sediment; LSU=lagoon seagrass/unconsolidated sediment; OLSM=outer lagoon seagrass/mangrove; LSM=lagoon seagrass/mangrove; LMU=lagoon mangrove/ unconsolidated sediment.

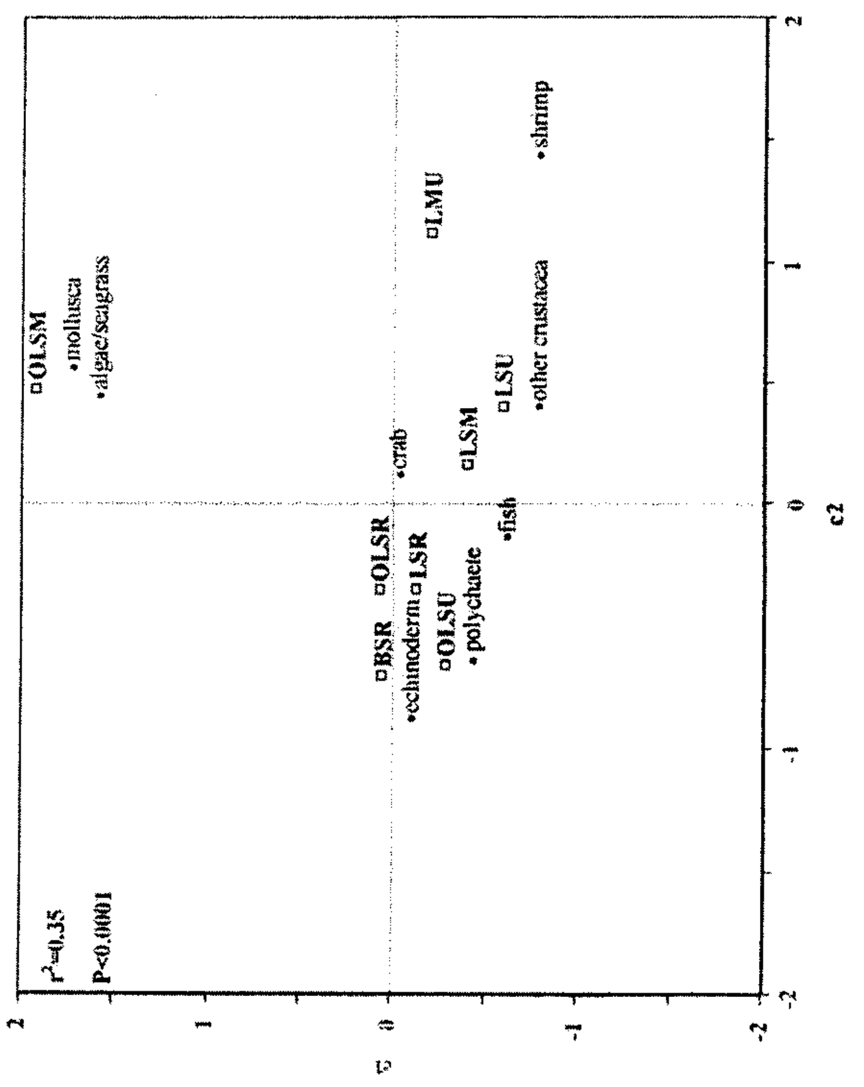

Figure 6. Correspondence analysis results displaying the relationship between bluestriped grunt prey identified from sampling strata (abbreviations as in Figure 5). Open squares represent strata ordination, while closed circles represent prey item ordinations.

DISCUSSION

Coral reef ecosystems can contain a variety of habitat types, such as mangroves, seagrass beds, algal beds, sand flats, channels, sand-rubble zones, and reefs. The linkages that exist between fishes and these habitat types are not well known (Ogden and Gladfelter 1983, Parrish 1989), and previous studies have typically focused on one habitat, reefs, or location (Springer and McErlean 1962, Hobson 1965, Weinstein and Heck 1979, Robblee and Zieman 1984, Stoner 1986, Sogard et al. 1987, Rooker and Dennis 1991, Burke 1995). While small-scale studies are important, examination of greater spatial ranges and ecosystem approaches provide the necessary information behind the concept of essential fish habitat (EFH) and the development of marine reserves (Christensen et al. 2003).

Results presented here provide strong evidence that many fishes exhibit dependencies on the range of habitats available to them for growth and reproductive success. Many species were strongly correlated with at least one habitat boundary, i.e. reef/seagrass, while several exhibited correlations for more than one habitat type. It is possible that this trend reflects ontogenetic shifts in habitat utilization; however, the sampling gear used is highly selective and typically captures adult and sub-adult fishes. These data provide information regarding habitat connectivity, showing that many species tend to exhibit resting or inactivity among highly structured habitats (reefs, mangroves) and venture to nearby seagrass and/or sand flats for feeding.

It is widely known that many fish species, such as grunts (Haemulidae) and snappers (Lutjanidae), demonstrate nocturnal migrations from protective complex habitats (reefs and/or mangroves) to less complex habitats (seagrass beds and/or sand flats) to feed (Hobson 1965, Collette and Talbot 1972, Ebeling and Bray 1976, Colton and Alevizon 1981). Typically, fish species exhibit ontogenetic shifts in habitat utilization and in the prey items they consume. Ontogenetic shifts in both habitat utilization and prey for the bluestriped grunt, *H. sciurus*, were observed in the study area. Although the sample size was small (n = 52), bluestriped grunts were significantly smaller in the nearshore mangrove and seagrass habitats than those captured near reef habitats. Larger grunts were also captured at outer lagoon seagrass/ unconsolidated sediment habitats, but these sites were restricted to back reef areas in close proximity to reefs (100-200 m) and were probably capturing grunts migrating to and from the reef. In addition, the results indicate a shift in prey items: juveniles consumed mostly crabs, shrimp, and other small crustaceans and adults fed on crabs, molluscs, echinoderms, and polychaetes. Similar investigations have displayed habitat connectivity for grunts and snappers (Christensen et al. 2003) within the same study area, and for french grunts, *H. flavolineatum*, in the Buck Island Reef National Monument, St. Croix (Kendall et al. 2003).

Randall (1967) has provided the most comprehensive description of prey items for over 200 fish species in Puerto Rico and the Virgin Islands and our results were similar. Linking prey items to specific habitats was difficult because we did not sample for them independently. These data can be qualitatively evaluated by examining prey items from fish captured at specific habitats. For example, Atlantic tarpon, *Megalops atlanticus*, were caught exclusively in the nearshore mangrove/unconsolidated sediment habitat and identified food items, such as fish and portunid crabs, were known to come from these habitats as by-catch in the gill nets and from visual fish census studies also conducted within the study area (Christensen et al. 2003).

These data are also being used to explore the transfer of energy across habitat boundaries. Fishes have been shown to be a significant source of organic carbon in marine ecosystems (Bray et al. 1981). Meyer and Schultz (1985) have shown that increased nutrients and organic matter provided by fishes stimulate coral growth and could possibly promote higher levels of biological activity in the benthic community beneath the coral colony. Further explorations of the data are being conducted to complement these results to better understand habitat function in coral reef ecosystems.

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